show the nebula to be a symmetrical ellipse, with a distinctly stellar nucleus in the midst of dense nebulosity which surrounds it. Outside this is a well-defined zone of faint nebulosity, and then a broad ring, or zone, with little if any nebulosity in it. Outside this, again, is a very dense broad ring of nebulosity, and a patch of very faint nebulosity extends beyond the ring at the *s.f.* end.

The nebula is probably a circular or oval system seen in perspective elongated, and there are indications of condensations of matter of the rings.

The nebula resembles, on a very small scale, the great nebula in *Andromeda*, and the description given by Lord Rosse agrees well with the photograph, though he could not have seen the details which are there shown.

The Variable Spectrum of β Lyræ in the Region of F—*h*.

By the Rev. Walter Sidgreaves, S.J.

In the August number of *Astronomy and Astro-Physics* Mr. Keeler has given us an interesting account of his experiences of the variations of the spectrum of *β Lyræ*. All observations of progressive or recurring changes in the starry universe, made with the great refractor at Mount Hamilton, are necessarily of the highest value; and those changes which are indicated to us by the delicate linings of a spectrum band seem to have greater claims upon the light-capacity of the great glass.

Mr. Keeler has drawn attention to the main difficulty which besets all eye observations of delicate changes, in his remark that it is necessary to preserve a faithful memory of an appearance noted perhaps many days past. Photography, here, has the advantage of presenting to the eye simultaneously both the past and the present state of things. And, for this reason, Mr. Keeler does not claim for his notes a value at all equal to the photographic impressions of the spectrum of *β Lyræ*, obtained with much smaller optical power. We think that he underrates the merit of his own work, and overrates the advantages of the photographic records. That these are considerable there can be no question. But it is not clear whether even greater allowance has to be made for the photographic plate than for the eye, under the diverse conditions of our treacherous atmosphere.

We cannot claim for the spectrographic plates of *β Lyræ* obtained at this observatory any such superiority over Mr. Keeler's notes upon his eye observations at Mount Hamilton. The star is only fairly within the working capacity of the 8-inch refractor on the clearer nights, and our recent examination of 45 plates shows that under these circumstances the

photographic plate may be more treacherous than the retina of the eye. The eye presents at least the same retina to the light rays, at all its observations; while the camera must change its plates. A little difference in the sensibility of the plate may greatly alter the value of the picture, when the light collector can barely provide sufficiency. An over-exposed plate can be dealt with fairly successfully in the process of developing; but an under-exposure can never be brought up to compare accurately with a plate that has had the advantage of the full action of light. Under-exposure has been the chief failing in the series of plates. It has not been possible to secure a full exposure on all occasions, owing to a defect in the clock movement as applied to the method of trailing. A small inequality in the thread of the driving-screw produces a periodic oscillation of a star about a mean position in the field when the clock is adjusted to true star time. And when the clock is slowed, the star travels across the field with a periodic variation of rate, and leaves on the photographic plate a spectrum band composed of a series of rulings. A slow trail, which corresponds to a long exposure, is shown on the plate by the closeness of the rulings; and the limit to the length of exposure is the rate of trail which gives an alternation between a complete halt and a march of the star's image; for if the image return upon its journey, the spectral lines must become blurred, unless the motion is more accurately parallel to the edge of the prism than can be secured without the use of a slit and constant attention to the instrument during the time of exposure. The difficulty of securing this adjustment for *β Lyræ* has been the cause of a number of failures; but the series of available plates numbers in all 45. Ten of these were taken in the spring and summer of 1892, on occasions of exceptionally clear nights, and the other 35 plates were the result of a set purpose to make as complete a collection as possible during the favourable position of the star in the last half of the present year. These were obtained between the third week of May and the middle of August, when the series came to an end with the last night of the 8-inch objective. The telescope was dismounted on August 16, in order to send its central box to Dublin to be fitted with the new tubes required for the Fr. Perry-Memorial objective. We may look for a more valuable record of the variations of the star's spectrum from the greater light power; but I have thought it well to offer the results of a very careful examination of the plates already obtained to the R.A.S. They may be confirmed or reversed by the more reliable plates of the future, but at least the comparison will show how far a weaker instrument can be trusted.

The spectrograph and its adjustments have been already described in the *Memoirs*, vol. li. p. 30. No alteration has been made in the instrument since its employment upon the

Nova of last year. The plates of β *Lyræ* have been arranged according to the day-age of its light variation, reckoned always from the preceding principal minimum.

In the accompanying map (Plate 2) the spectrum is given for each day-age, except day 10, for which there is no photograph, but only the more prominent lines have been marked. There are on some of the plates many more lines and bands which undoubtedly go through considerable changes. These have been omitted as not being sufficiently within the optical power of the instrument.

The wave-lengths are quoted from the curve constructed for the *Nova* of last year. They are referred to the position of G′ at the marginal separation of its bright and dark representatives on the first days of the variation period, and the red side edge of the absorption line has been retained for the fiducial position for all plates not showing the red side radiation. The red side edge of F has also been employed as a second or corrective fiducial point on those plates which showed it with sufficient certainty. On some of the plates it was doubtful whether the line was F or a stranger, and on these plates it was not employed as a reference position.

It seems probable, from our examination of the plates, that the star's spectrum varies in general with its light period; for whenever there are more photographs than one for the same day-age, the same spectrum on the whole is shown on all the plates, making proper allowance for more and for less successful exposures. But there are exceptions which may eventually be brought into better harmony with some other period than that of the light curve. The most notable of these is shown in the map for the 11th day, which will be referred to again in our remarks upon the separate lines; and there may be others, if our estimation of the relative value of the photographs is much in error. But the terms maximum and minimum, as applied to prominence or strength of the radiation lines, do not appear to run with the corresponding epochs of the light curve. The maximum display of bright lines is between the 1st and 2nd day after the principal minimum, and the changes appear to be quite abrupt; for on the 11th and 12th days the bright lines are quite weak on good plates, and on the 13th day, a few hours before the principal minimum, the spectrum is still without bright lines.

Of the individual lines shown in the map, F is probably the one we should say least about, for the sensibility of the plates employed upon the star falls off rapidly at this region of the spectrum. But the contrast between the relations of F and G′ in the spectra of β *Lyræ* and γ *Cassiopeiæ* is noteworthy; viz., that with the same instrument and the same plates, F is much stronger than G′ in γ *Cassiopeiæ*, and generally much weaker in

β Lyræ. Its inferiority in *β Lyræ* may be a photographic deception; for it is possible that the actinic energy of the F rays may increase more rapidly with the increment of light than that of the rays of G′.

The companion lines at λ471 seem to have a variation of their own, besides the general waning to extinction shown in the map. They are very strongly marked on the two best plates belonging to day 1; but they are wholly absent from the two very good plates of day 2, while a third plate of this day-age shows them quite clearly.

The group of lines at λ447–8 is perhaps the most prominent feature in the spectrum. The stronger absorption line at the blue side fades away rapidly after the 3rd day, and the middle radiation line begins about the same time to divide, and gradually increases in the width and separation of the parts until the 11th day, when every part of the group is completely extinct on three plates belonging to this day-age, two of which are much too good to deceive. The reappearance of the absorption lines on the 12th day, without any bright companions, is also quite certain; two very good plates of this day-age bear witness to this, two ill-defined ones confirm them, and one inferior plate is doubtful.

λ438 and G′. The radiation component of line 438 dies gradually from day 1 to day 4, when it is almost if not quite dead; while the absorption retains its full strength till the same 4th day, when it suddenly collapses with its companion. On the 7th day a new order has apparently just commenced; the absorption line has barely recovered, but the radiation has passed from its red to its blue side, and the same change has simultaneously commenced in the pair at G′. Both the components of G′ have slowly lost their strength during the 4th, 5th, and 6th days; a more rapid decline has set in after day 6, and on day 7 the dark and bright companions appear faintly in the reversed order. The radiation is now on the blue side of the absorption. The absorption is narrow, and the radiation broad and undefined. Both are exceedingly weak, but are not doubted. On the 8th day the new order of the lines is quite manifest, and on the 9th they have attained apparently their maximum intensity, with the absorption quite equal to those of the first days, and the radiation about the same as on the 5th day. The same order is retained until the 12th day, the radiation fading slowly to nothing on this day, while the absorption remains unaltered till the 13th day, when it has suddenly vanished.

From this it appears that the reversal of the relative positions of the bright and dark components of G′, and also probably of the weaker pair at 438, takes place at the secondary minimum, and again at the principal minimum, for the date of the 7th-day plate is ten hours after the secondary minimum, and this plate just

shows the change of position; and the date of the 13th-day plate is two hours before the principal minimum, and here both components of G are nearly completely obliterated. We have, however, the evidence of only one date for each of these day-ages—the 7th and 13th; viz., two plates for the *same* 13th day, and a single plate for the 7th day. But their evidence has recently been confirmed by a fortunate trial plate upon *β Lyræ*, with the same spectroscope mounted upon the Fr. Perry-Memorial telescope. This plate is of the same light age as the 7th-day plate of the series, having been exposed at 9 hours after the secondary minimum, and it shows the same approximate obliteration of G′ as is sketched on the 7th day of the map. Two other trial plates with the new objective confirm the succession of changes in G′ as given by the series of exposures with the old 8-inch glass. One of these fills the gap of the 10th day, and shows the spectrum of the 9th day, with a small diminution of intensity in the absorption and radiation components of G′, so far as we can judge between the different conditions of the exposures; those of the 9th day being by slower trails with less light, and that of the 10th by a quicker trail and more light. The remaining trial plate was, as soon as developed, pronounced to be a 1st- or 2nd-day plate; and was found, on reference to the *Companion to the Observatory*, to belong to the 1st day, at 11 hours after the principal minimum.

The remaining line at λ410 is at a weak part of the plate. The absorption is clearly seen on all the days except 7 and 8, and this change on the 7th day is confirmed by the stronger photograph already mentioned, which has it only as a mere ghost. No plate of the series shows the companion bright hydrogen in this region, but the stronger photograph of the 1st day by the new objective shows it clearly on the red side like its kin-fellow at G′.

In summarising our conclusions we give them as they come from our own photographs only, without reference to the conclusions drawn from observations with other and better instruments.

1°. It is quite certain that the hydrogen line at G′ is at times double, one part being bright and the other dark.

2°. It is quite certain that the bright component is sometimes on the red side and sometimes on the blue side of the absorption line.

3°. It is highly probable that this change is periodical and coincident with the two minima of the light period.

4°. It is probable that the obliteration of both components at the times of the minima is due to neutralisation by their superposition.

5°. It is uncertain whether the bright component passes

across the dark one as a stationary line, or the two exchange positions.

6°. It is probable that the bright lines are strongest during the first three days of the light period.

The periodic change in the relative position of the two components of G′ agrees very closely with the result of Professor Pickering's examination of the Harvard College photographs, as given in *A.N.* No. 3,051, and confirms his supposition of the binary nature of the star; but a rather elongated ellipse would suit the quickness of change at the minima of brightness, and the other requirements of our map, better than a circular orbit. The major axis being nearly in our line of sight, and the smaller and cooler star being between us and its primary at periastron, the continuous spectrum would be weakened by the partial eclipse; and the bright lines might be brought to their maximum intensity just after periastron by the heat developed in the tidal action upon the smaller star. They would at first be neutralised by the absorption lines while the star was crossing our line of sight, and would appear on the red side of the absorption, as soon as this rectangular inclination of the motion was sufficiently reduced. This would occur soon after the principal minimum, considering the high velocity at this part of the orbit and the short time-period of the revolution. The bright lines would retain their strength for some days, and then might cool down gradually to extinction before the next periastron. At the apastron there would be an eclipse of the smaller star, corresponding to the secondary minimum of brightness, and there would be a repetition of the superposition of the bright and dark lines, causing a temporary suppression of both, to be followed by the reversal of their relative position.

All these changes are faithfully followed by the hydrogen light at G′, and the irregular appearances of other lines are to be expected from the nature of their origin in a tidal commotion. But at the precise epoch of a secondary minimum the dark hydrogen line should be visible without its radiant companion; and if this be discovered, it will greatly strengthen our confidence in this explanation of the variations of the spectrum of *β Lyræ.*

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